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A mask aligner model Suss MJB3 UV/IR Mask Aligner to support our on going research was proposed for acquisition and the proposal was approved. An upgrade package for an RIB system was also proposed. However, due to limited funds only the funds for the mask aligner was made available. Consequently, the RIB upgrade portion of the proposed activity was not implemented. The mask aligner got ordered, received, and brought on line in June 2002 rapidly. It has been in use ever since and operating smoothly.

The newest addition to the lithography equipment is a Karl Suss MJB3 mask aligner. Some of the features this model garnishes are UV 300 and liv 400 exposure source and front and back side illumination. The aligner is capable of producing about 0.5 j.tm line widths. Available front exposure and viewing, and back viewing allow alignment of the front patterns with respect to those on the back. The unit is either used by or support of research of some 25 researchers at VCU microelectronics center. A photograph of the exposure system is shown in Fig. 1.

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DURIP 02 Final Report (Award No. F49620-02-1-0212) for

Request for Mask Aligner and Upgrade for a Reactive Ion Etcher

June 15, 2001-June 14, 2003

Prepared for

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Summary

A mask aligner model Suss MJB3 UV/IR Mask Aligner to support our on going research was proposed for acquisition and the proposal was approved. An upgrade package for an RIE system was also proposed. However, due to limited funds only the funds for the mask aligner was made available. Consequently, the RIE upgrade portion of the proposed activity was not implemented. The mask aligner got ordered, received, and brought on line in June 2002 rapidly. It has been in use ever since and operating smoothly.

The newest addition to the lithography equipment is a Karl Suss MJB3 mask aligner. Some of the features this model garnishes are UV 300 and UV 400 exposure source and front and back side illumination. The aligner is capable of producing about 0.5 μm line widths. Available front exposure and viewing, and back viewing allow alignment of the front patterns with respect to those on the back. The unit is either used by or support of research of some 25 researchers at VCU microelectronics center. A photograph of the exposure system is shown in Fig. 1.

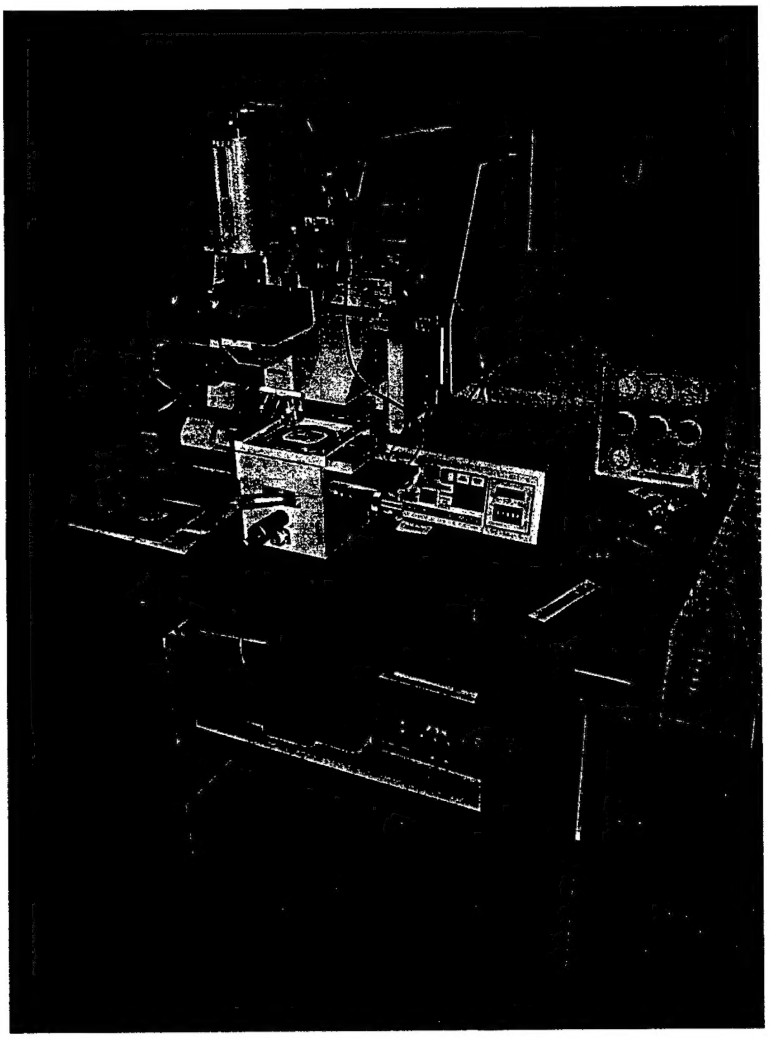

Figure 1. Suss Microtech MJB3 aligner with 300 and 400 nm exposure as it stands in the third floor clean room of Virginia Microelectronics Center.

The floor plan of the clean room and Electrical measurement capabilities are shown in Fig.2. For an interactive version of it, please visit the URL for our laboratory http:// www.engineering.vcu.edu/fac/morkoc. Additional information is provided at the end of this report.

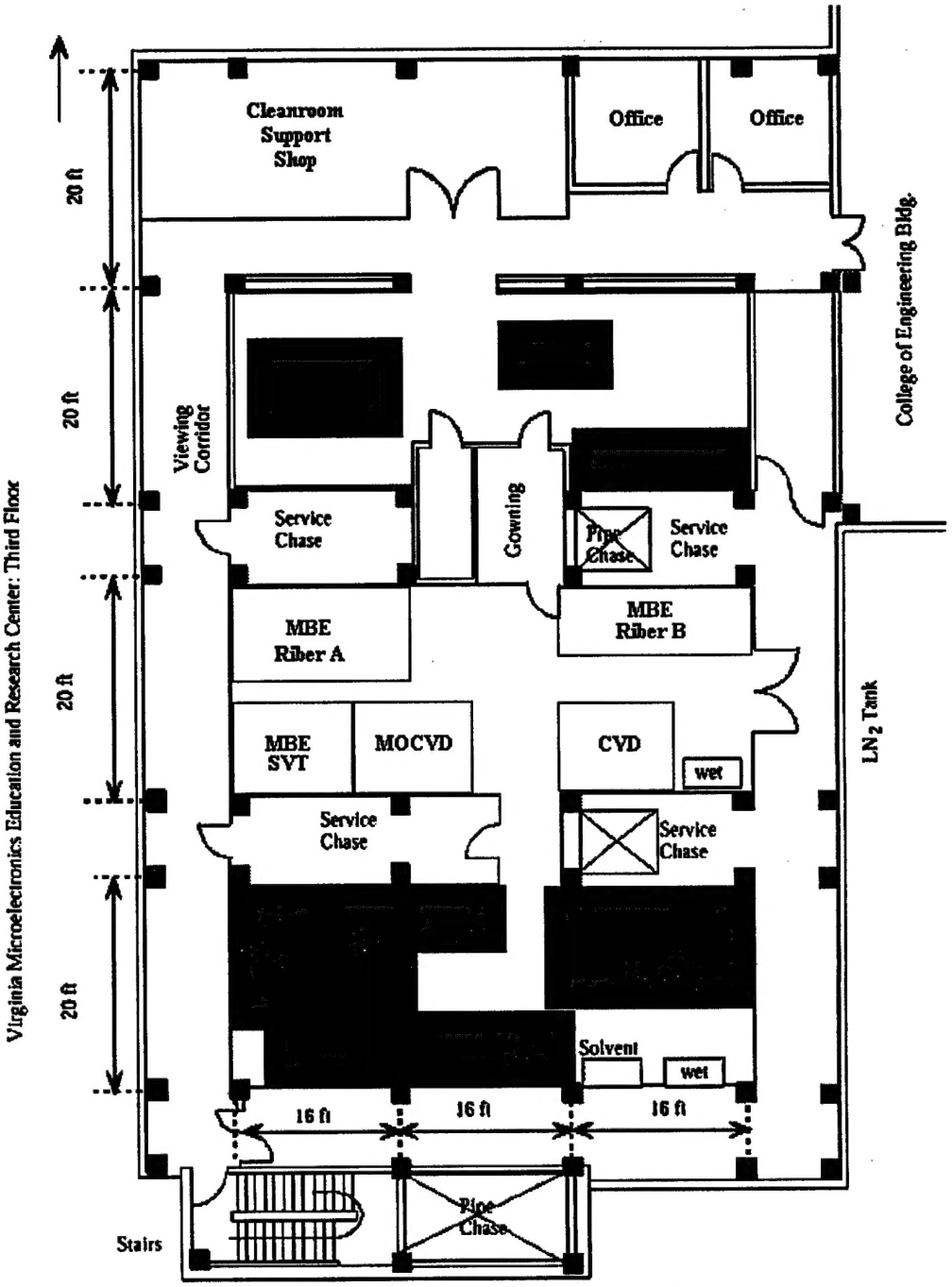

Fig. 2. Floor plan of the research present equipment and clean room in the Virginia Microelectronics Center. Layout of the research present equipment and clean room in the Virginia Microelectronics Center.

Budget allocation and detailed equipment purchases

Morkoc, Hadis **Equipment Grants**

Acct. #	Agency	grant #	Start	End	Amount
5-28817	AFOSR	F49620-02-1-0212	June 15, 2002	June 14, 2003	$101,450.00

Total Expenditures/Commitments	**$101,450.00**
Cost Sharing	**$0**
Balance Remaining/Available for Expenditure	$0

Biographical Sketch of the Principal Investigator

Biographical sketch

Hadis Morkoç

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A. VITAE

EDUCATION

1973 - 1975	Ph.D. degree in Electrical Engineering, Cornell University (Advisor: Prof. L.F. Eastman)
1971 - 1973	Ph.D. candidate in Electrical Engineering, Michigan State University (Advisor: Prof. L.J. Giacoletto)
1968 - 1969	MS degree in Electrical Engineering, Istanbul Technical University
1964 - 1968	BS degree in Electrical Engineering, Istanbul Technical University

PROFESSIONAL EXPERIENCE

1997-present	Founders Professor of Electrical Engineering, Virginia Commonwealth University, Richmond, VA.
1995 - 1998	University Resident Research Professor, Air Force Research Laboratory, Wright Patterson Air Force Base, OH.
1987 - 1988	Distinguished Visiting Scholar, Jet Propulsion Laboratory and California Institute of Technology, Pasadena, CA.
1978 - 1997	Assistant and Associate Professor of Electrical Engineering and Research Associate Professor of Coordinated Science Laboratory, Univ. of Illinois, Urbana-Champagne, IL.
1986 - 1997	Graduate Faculty, Dept. of Physics and Material Science and Engineering, Univ. of Illinois, Urbana-Champagne, IL.
1978 - 1979	Resident Member of Technical Staff, AT&T Bell Laboratories.
1976 - 1978	Member of Technical Staff, Central Research Laboratories, Varian Associates, Palo Alto, CA.
1975 - 1976	Postdoctoral Fellow, School of Electrical Engineering, Cornell University, Ithaca, NY.

PROFESSIONAL AFFILIATIONS

Fellow: Institute of Electrical and Electronics Engineers (IEEE)
Fellow: American Association for the Advancement of Science (AAAS)
Fellow (life): American Physical Society (APS)
Member: Material Research Society (MRS), Eta Kappa Nu, Phi, and Sigma Pi Sigma
Life member: Sigma Xi, Phi Kappa Phi
Listed in Who's Who in the Midwest, American Men and Women in Science, Who's Who in America, Who's Who in Engineering, and International Men of Achievement.

According to Institute of Scientific Information and since 1982, the research papers of Dr. Morkoç have been cited some 15, 000 times. Moreover, in a field encompassing, condensed matter physics, electronic materials, metallurgy, ceramics, polymers, and materials chemistry, and in the five year period 1990 - 1995 and for all publications world-wide: Dr. Morkoç was listed as 18th and 4th in the total number of citations and the Citation Impact (number of citations per paper), respectively, see Science Watch, Vol. 6, No. 9, October 1995, and the Journal Science, October 20, 1995. According to the same organization, Morkoç ranked 19th among 517,111 physicists in terms of citations and citation impact between 1981 and 1997. There ahead of him were collective efforts of several physicists who shared the same last and first names. He is one of only nine who are listed in more than one category, which in his case are Engineering and Physics, see http://www.isihighlycited.com

Publications

He has authored a book on nitride semiconductors and devices (Springer Verlag 1999, the second edition is in progress) and a two-volume book on MODFETs, editor of a three volume book on Advanced Semiconductor & Organic Nano-Techniques, some 37 book chapters, 45 tutorial-review-popular articles dealing with heterostructures, electronic and optoelectronic devices, and some 1150 technical articles. He delivered some 57 invited talks at major international meetings and some 110 seminars at various laboratories and universities around the world.

Facilities available in the Virginia Commonwealth University Microelectronics RESEARCH LABORATORY

Multifunctional Materials and Devices Laboratory (VCU)

The proposed research will also involve facilities at Virginia Commonwealth University. The Multifunctional Materials and Devices Laboratory at the Virginia Commonwealth University's Microelectronics Center is equipped with state-of-the-art semiconductor deposition, fabrication, and testing equipment. These facilities are used to grow a wide variety of semiconductor and crystalline oxides, fabricate devices, and then characterize the quality and properties of the devices or samples.

The micro and nano-electronics research and education is performed in the Virginia Microelectronics Center (VMC), a 27,000 square foot four-story building. The first floor of the VMC is devoted to silicon technology and undergraduate education. The necessary equipment is being installed as provided by Motorola, Inc. The sponsored research programs are conducted on the third floor of the VMC which has approximately 2500 square feet of class 1000 space. Even though the laboratory receives new tools continually, already, an MBE system designed for depositing nitride semiconductors has been installed and calibrated. The SVT Reactive MBE system is also equipped with an RF nitrogen source for maximum flexibility. In addition, the workhorse, perhaps the most well known MBE system in the world that the group of Prof. Morkoç has used since 1979, is producing device quality layers. This Riber 1000 MBE system has been converted to reactive MBE system. A Riber MBE 3200 has been installed with appropriate sources, heater design and sources for crystalline oxide deposition.

A custom MOCVD system designed for semiconductor nitrides has installed, and optimization runs are in progress. This custom MOCVD system has a gas manifold and deposition reactor which were manufactured by EMCORE Corporation and SVT Associates, respectively. The system gives the group the added flexibility and advantage for nitride research. It has tremendous latitude in terms of gas delivery and eliminates

much of the interdependence among the parameters that often hampers conventional MOCVD systems. Another MOCVD system incorporating the latest technology in terms of inert materials has been delivered and is in under integration with growth tests slated for June 2003. Additionally, a custom made HVPE system is near completion in terms of installation.

On the fabrication side, the research laboratory is equipped with photo (two contact mask aligners one with 300 nm UV exposure) and electron beam lithography systems and metallization and etching facilities. The LEO 440 microscope has a 2 nm resolution in the imaging mode and is layered with a Nabity pattern generation system. The research oriented RF dry etching system was designed in the plasma group at Wright Patterson Air Force Research Laboratory. This system is designed for convenience and low damage and is easily configurable for plasma diagnosis for an easy correlation of plasma parameters to etching characteristics. Moreover, a load locked sputtering system with DC and magnetron sources is available and being used for oxides in conjunction with wide bandgap semiconductor research. We are in the process of bringing on line an inductively heated furnace for H-etching and annealing of wide bandgap semiconductors.

Another tool, KLA Tencor Alpha Stepper 500 surface prolifometer, is capable of mapping the surface topology. This is a very versatile system for precise measurement of very thin step heights on wafers and small samples. Flexible software allows analysis of up to 39 surface parameters with simultaneous display. Moreover, we added a Digital Instruments Nanoscope III multimode AFM and Dimensions 3100 AFM with EFM and CAFM capability which are pivotal in characterization of layers including structural defects and charge states.

Through an NSF MRI program, we have added a Philips X'pert MRD high resolution (10 arcsec which can be upgraded to 5 arcsec) X-ray diffraction system in 1999. X-ray diffraction (XRD) is a versatile analytical technique used in our research to analyze structural properties of crystalline materials. At VCU the system will be used for high resolution applications – such as rocking curves of heteroepitaxial layers; diffraction space

maps of thick hetero-epitaxial structures and partially relaxed structures; reflectivity measurements of layer thickness, interface/sample quality and density, and structural properties of nano-structures. The X'Pert - MPD system utilizes specially developed PREFIX (pre-aligned, fast interchangeable) optical modules which enable switching from application to application by simply swapping the optical module. Dedicated analytical instrument performance is ensured due to the wear-free reference surfaces on the PREFIX modules. The MRD cradle provides the versatility of an open Eulerian cradle, an x-y stage and z translation to accommodate applications needing utmost accuracy.

Extensive optical characterization facilities, which allow PL, absorption and reflectance measurements in semiconductor nitrides and other samples, also exist. The recently acquired Ti-Sapphire laser with Second Harmonic Generation (SDH) and Third Harmonic Generation (TDH) allows tunable wavelengths in the ranges of 700-100nm and 235-500 nm with picosecond temporal capabilities. In addition, He-Cd, N and Ar lasers are also available. The detection scheme is based on photon counting with excellent signal to noise ratio. The laboratory also has several cryostats. A diamond anvil cell with its associated optics, optical sources, a fast CCD detector, and 1.25 m spectrometer is in the process of being commissioned.

A Lake Shore Model 7504 Hall Effect Measurement System with automatic data acquisition system in the temperature range of 10-300 K and magnetic fields up to nearly 1 T was added. This instrument is used to determine carrier concentrations and mobilities in semiconductors, and allows the determination of scattering processes taking place. A Keitley 4200 parameter analyzer, which is PC based, with below fA and above 1A current measurement capability, and coupled with a Karl Suss PM 8 shielded probe station provides an accurate and rapid evaluation of I-V characteristics. In addition, a temperature dependent I-V and C-V measurement capability is available with metrics software and Keithley electronic switch box for versatility in the choice of instrument connected to the device under test. The facility will soon receive an optically assisted Sula Technologies DLTS system with substrate temperature up to 700 C.

The deposition and fabrication laboratories enjoy conveniently delivered utilities such as gaseous and liquid nitrogen, process vacuum, compressed dry air, process cooling water, DI water, scrubbed and regular exhausts, and much more. The airflow system for class 1000 is designed to diffuse the air in a way to be extremely quiet. This combined with all the roughing pumps and compressors being located in service bays lend to a very comfortable and environmentally friendly laboratory space in which to work. Moreover, the group has electrical and optical characterization laboratories giving the researcher full access to a full range of equipment to carry out research without leaving the laboratory. The group has a long term working relationship with many specialists across the country and abroad for research requiring expertise and training not available on site.

For more details, pictures, and layout of the laboratories, please visit http:// www.engineering.vcu.edu/fac/morkoc

Attachments: The quote from Suss Microtech and the acceptance letter of the order by the same.